SYNTHETIC APERTURE SONAR PRIMER

Frank Henyey
Applied Physics Laboratory
University of Washington
Seattle, Wa. 98105

Kevin Williams
Applied Physics Laboratory
University of Washington
Seattle, Wa. 98105
Award# N00014-95-1-0532

LONG TERM GOALS

The goal of the Synthetic Aperture Sonar (SAS) primer is to understand the effect of the ocean water properties on the propagation of acoustic signals for frequencies and horizontal ranges that are applicable to SAS Navy systems currently being developed. The oceanographic phenomena being examined in this regard are internal waves and turbulence.

SCIENTIFIC OBJECTIVES

Our objective is to quantify the effects of internal waves and turbulence on the imaging capabilities of SAS systems. We want to develop and test models that use measurable oceanographic parameters as inputs in predicting the limitations imposed on SAS by the environment .

APPROACH

Our approach has been to develop models of the effects of internal waves and turbulence (Henyey, et al) and the to test these models experimentally. The experimental test occurred in conjunction with the Coastal Mixing and Optics program in August 1997 and included both oceanographic and acoustic measurements.

WORK COMPLETED

The experimental arrangement is shown in figure 1. The source/receiver towers were separated by about 800 meters so that acoustic data could be collected for both the lower path and upper path shown in the figure. Approximately 3 days of autonomous data were recorded during the experiment . See the FY96 year end report for details.

The data show that there are extreme changes in the acoustic paths when solibores pass through the experimental region (twice a day). The initial data analysis concentrated on one day of deployment for which there are time periods of rapid changes due to solibores and more quiescent times where the oceanographic data indicate the usefulness of a Garrett-Munk type model for internal waves. More detailed analyses have concentrated on

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**
4. TITLE AND SUBTITLE **Synthetic Aperture Sonar Primer**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Laboratory,1013 N.E. 40th Street,Seattle,WA,98105**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

the effects of internal waves on the lower path for three 30 minute time windows on August 22nd where the media effects seemed smallest and a modified Garrett-Munk model could be used. This has allowed both a quality check on the data and a model/data comparison on the effects of internal waves on SAS image resolution during relatively benign times

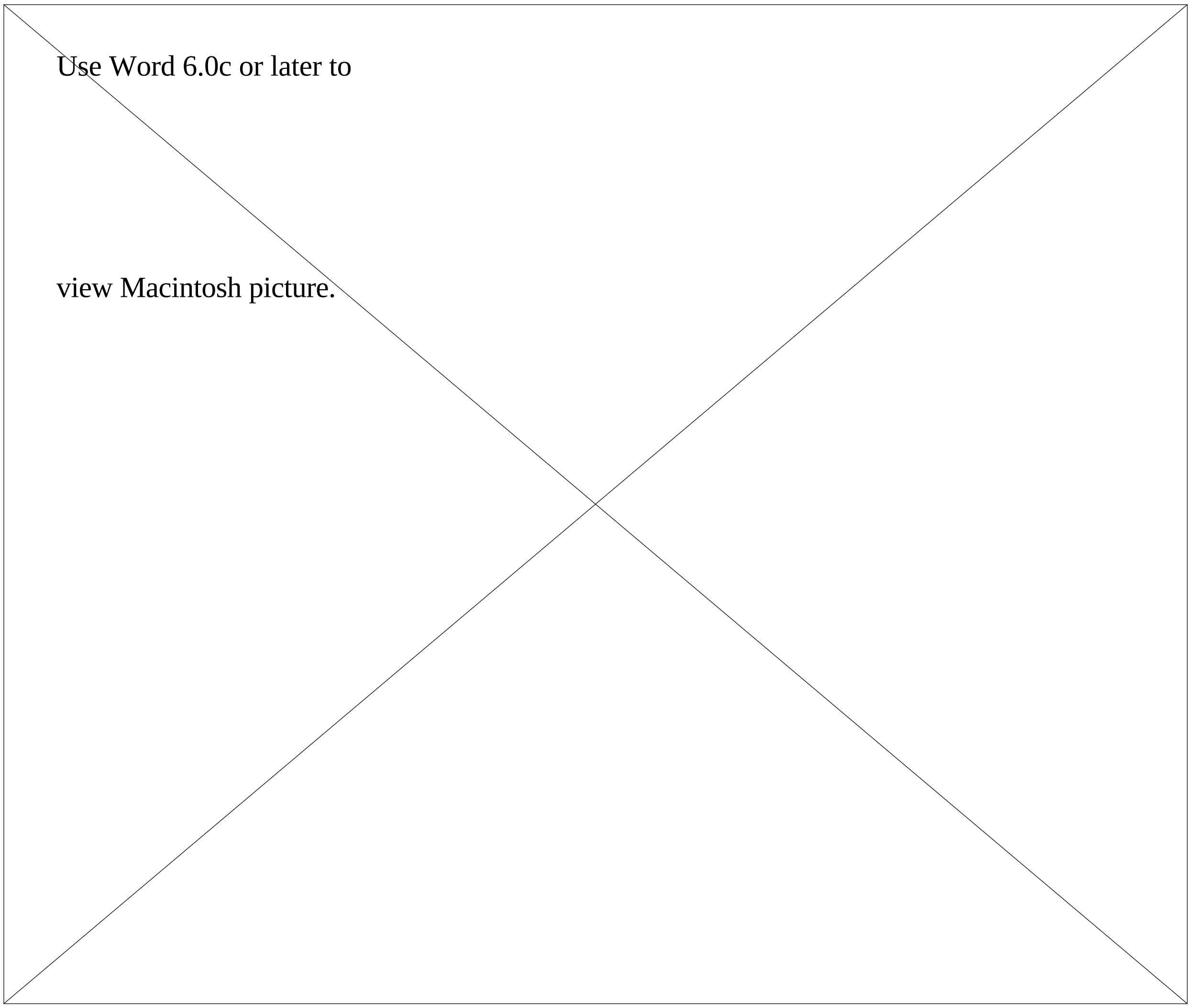

Figure 1 - Simplified diagram of the SAS experiment.

RESULTS

Figure 2 summarizes the model/data comparison for the periods examined. The figure compares the predicted and measured resolution limitation due to internal waves for the time periods examined. The results are for a 75 kHz source with a 814 meter propagation distance. The salient point is that internal waves effect the wave curvature and thus can limit the resolutions obtainable to values well above those calculated for an ideal situation. However, under some conditions autofocusing can mitigate these effects (Henyey, et. al.).

Such would be the case for the time periods examined in figure 2.(i.e., with autofocusing the ideal limit could be recovered)

Figure 2 - The resolution of a sonar (real or synthetic) is a function of its aperture size. When internal wave effects on the wave curvature are taken into account there is an optimal aperture size if autofocusing is not used (Henyey et. al.).All curves are for a 75 kHz source with a range to receiver of 814 meters. In a) model results are shown for the predicted resolution of a SAS as a function of aperture size. The sum curve indicates an optimal aperture size of about 15 meters. The model uses a modified Garrett-Munk spectrum with parameters chosen to fit the on-site measured oceanography. In b) the mean value of the measured internal wave effects for three 30 minute periods is shown (solid lines) along with the results at plus and minus one standard deviation (dotted lines). The periods chosen were during the most quiescent times on August 22nd. More detailed

examinations of the results indicate that we are at the limit of our measurement capability during these times.

IMPACT/APPLICATION

Two inferences can be made from the results to date. First, solibores passing through the area of SAS operation can dramatically effect the operation range and therefore the area rate coverage during a significant period of each day (during the SAS experiment solibore effects on the temperature profile were obvious for at least two hour after the passing of a solibore). Second, under the most benign conditions of the experiment a SAS operating well below the thermocline and using acoustic paths that didn't traverse the thermocline could significantly mitigate media effects by autofocusing.

TRANSITIONS

An invited talk was given during the 133rd meeting of Acoustical Society of America in a special session on Synthetic Aperture Sonar. At that meeting we began discussions with the SAS group at Hughes. They recently gave a talk to us at APL on their work. Their SAS, built and operated under DARPA support, closely matches the parameter regime (frequency, range, etc.) of our experiment. So far, it has only been operated under benign conditions; our work will become relevant when it is operated in strong internal wave conditions.

RELATED PROJECTS

Upper Path at MATE is a project to understand how existing theories need to be modified for the case of upper paths that change inside a correlation length of the medium. The upper path at an old experiment, MATE, is compared and contrasted with the upper path in the SAS experiment.

Solibores and Sill Flows is a project which includes the study of the hydrodynamics of solibores, which were the dominant internal wave at SAS, and have a profound effect on the data.

REFERENCES

Frank S. Henyey, Daniel Rouseff, James M. Grochocinski, Stephen A. Reynolds, Kevin L. Williams, Terry E. Ewart, "Effects of Internal Waves on a Horizontal Aperture Sonar," IEEE J. Ocean Eng., 22, 1-11 (1997)